Saturday Morning Physics - Accelerators

Accelerators

• What's Up Now?

- What's Up Next? <<< We Are Here ...
- http://tdserver1.fnal.gov/Finley/040327_SMP_TWO.pdf

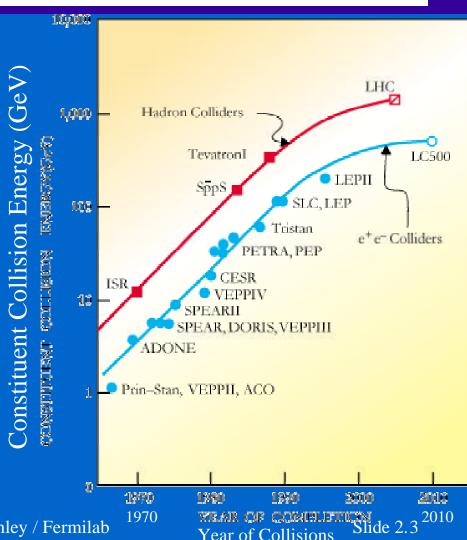
Accelerators - What's Up Next?

- What Up Next?
 - positrons and electrons: e⁺e⁻ Colliding Beams
 - protons and protons : pp Colliding Beams
 - antimuons and muons : μ⁺ μ⁻ Colliding Beams
 - neutrino beam : From decaying muons

But first, a word about recent times ...

Recent Times ...

- Physics Today January 2001
 - Maury Tigner (Cornell University)
- Comparing hadrons and leptons
 - Constituent hadron collision energy is about 1/10 of total hadron beam energies
 - Constituent lepton collision energy is all of total lepton beam energies
- Leveling off? ... yes ... why?
 - It's a fact of life if you keep using the same concepts and evolve with the same basic technology

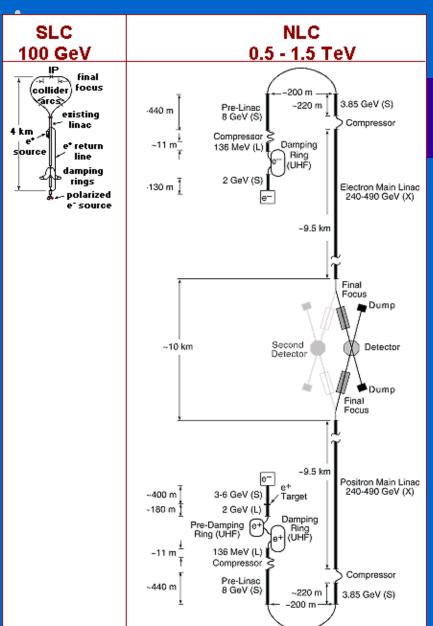


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e⁺e⁻ Linear Colliders

- The good news is:
 - The electron is a lepton
 - A point (so far as we can see)
 - Simple particles give simpler interactions
 - Precision tool (if you know where to look)
 - Q4: How is it that we see more matter than antimatter?
 - Q2: How does it all behave?
- The bad news is:
 - Not much mass ...
 - radiates photons like crazy when you deflect them
 - (This is a good thing at Argonne ... but a bad thing for e⁺ e⁻)
- A "feature" is: Single pass ... no recirculation.



• The NLC is an e+e- Option.

(NLC = Next Linear Collider)

Two straight accelerators about 10 km long each providing 250 GeV beams.

- Several smaller (and rather complicated) accelerators and devices to feed them ... 2 GeV, 3-6 GeV, positron target, 3.85 GeV, damping rings, compressors
- A pair of final focus lines, a detector, and a beam dump.
- Total Length = about 30 km.

(SLC = SLAC Linear Collider)

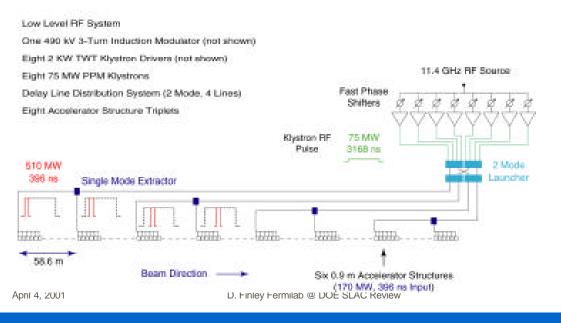
(SLAC = Stanford Linear Accelerator Center)
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Saturday Morning Physics

Schematic of NLC RF Test

ETF (Engineering Test Facility)

- March 2001 Version shown
- About 400 meters long
- 6 RDDS 0.9 m structures per girder shown
- Tests Power Sources, DLDS, Structures

NLC Linac RF Unit



Fermilab is developing a long term plan for performing this test in a refurbished fixed target beam enclosure ...

see next slides

A Tunnel for an NLC RF Test



The ETF enclosure is mostly empty now ... and that is good!

And Building for an NLC RF Test

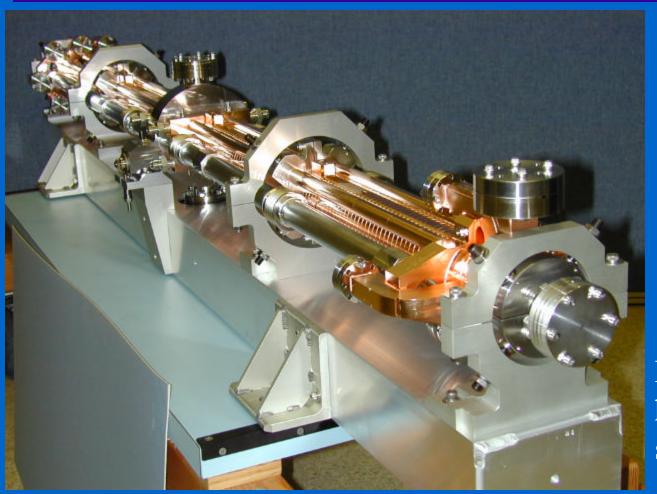


The MP9 building is now being used to make parts of the CMS detector for the LHC ...

but it can be reused for the ETF.

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1.8 meter long NLC RF structure

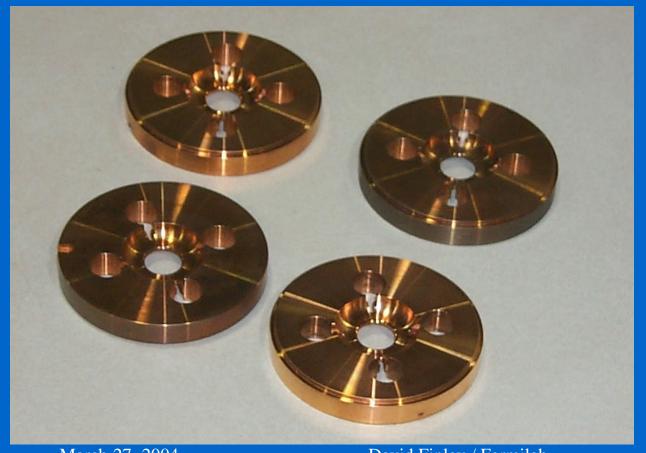


Made by the KEK lab in Japan and tested at the SLAC lab in California

Each structure has 206 disks ... see next slide

NLC RF copper disks

Each disk has a 61 mm outer diameter and 8 mm thickness.



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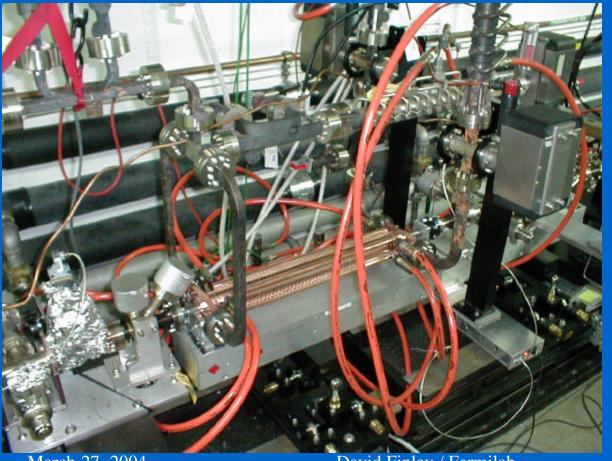
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The electron or positron beam goes through the center hole and unwanted energy is taken away in the four side channels.

Need 2,000,000

Fermilab and NLC "Structures"

FXC-001 installed at SLAC in January 2004 awaiting high power testing.



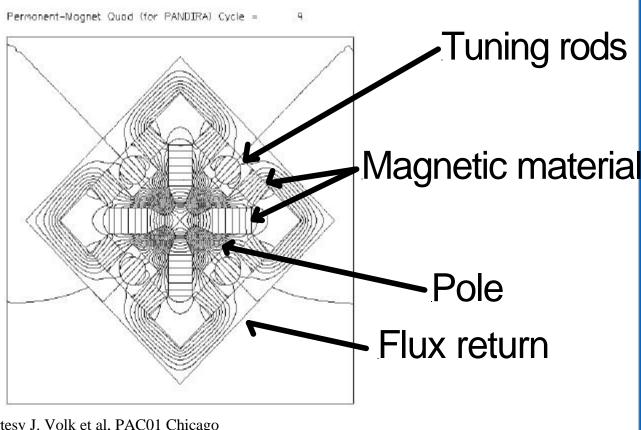
High Power Goals:

- 60 MV/m accelerating gradient
- 400 nsec
- 120 Hz
- < 1 spark / 10 hours

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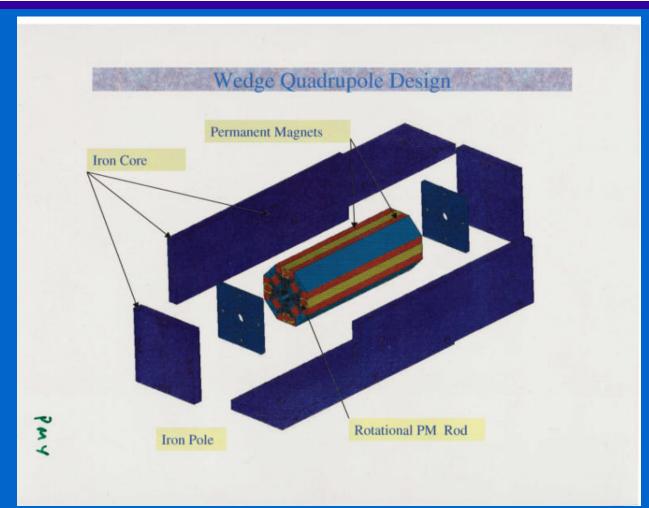
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Concept



Courtesy J. Volk et al, PAC01 Chicago

Design



Courtesy J. Volk

Reality





Measure the fields



Think.

Realize temperature control is important.

Courtesy J. Volk

Measure the fields while controlling the temperature ...

Control the Temperature ...



Think.

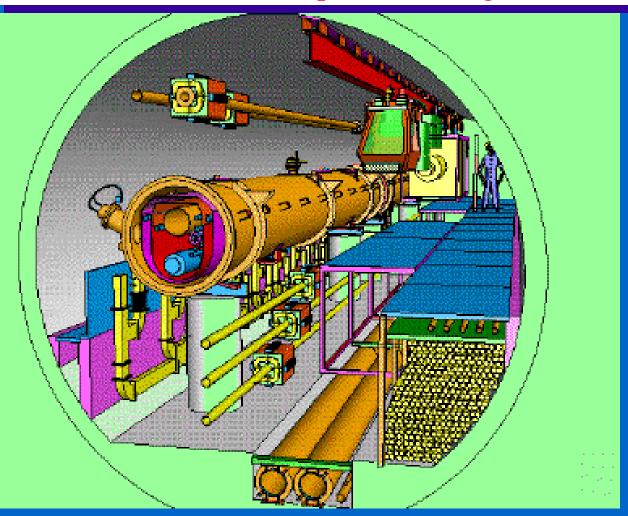
Modify the design ... etc etc

Courtesy J. Volk

f

TESLA from DESY is also an e⁺e⁻ Option

(TESLA = TEv Superconcucting Linear Accelerator)



The DESY lab has proposed an e+e- collider.

The accelerator is made of superconducting rf cavities.

The tunnel is about 5 meters in diameter.

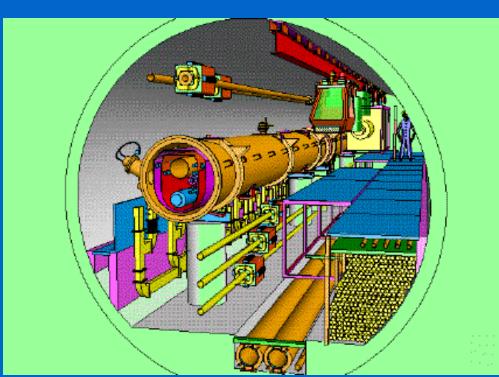
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TESLA & NLC Tunnel Sketches

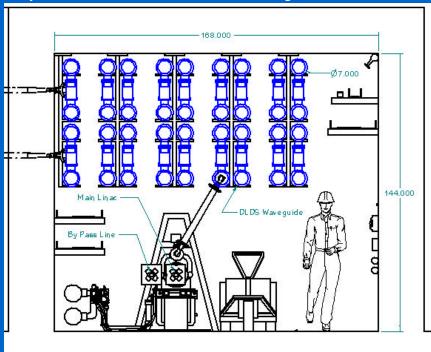
TESLA Main Linac Beam Enclosure.

Modulator & refrigerator enclosures / buildings not shown.



NLC Main Linac Beam Enclosure.

Klystron & modulator enclosures / buildings not shown.



Tunnel is 5.2 meter diameter

Tunnel is 12' high and 14 ft wide (3.66 m x 4.27 m)

The Size of a Linear Collider

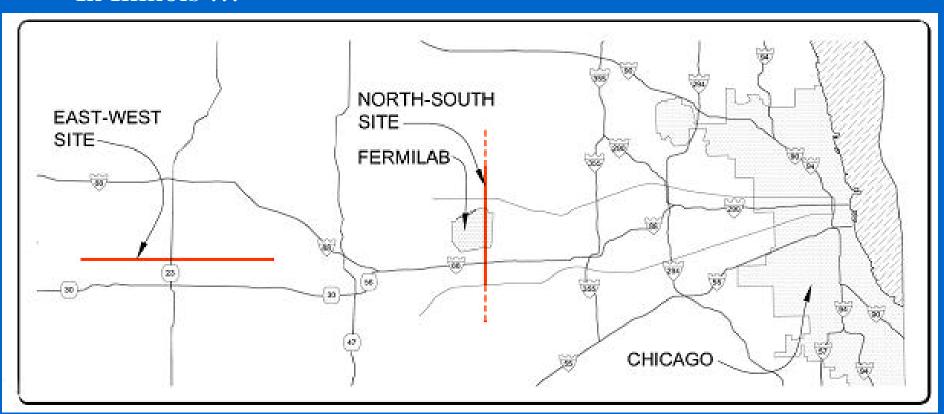
In California ...



f

The Size of a Linear Collider

In Illinois ...



Protons on protons

- The good news is:
 - We know how to do this ... standard techniques
 - This gives us the energy frontier
 - This is the path to discovery
 - Q1: What's it all made of?
 - Q2: How does it all behave?
- The bad news (if any) is:
 - It gets to be very large ...(see later slides)
 - And some* say wait for LHC results.

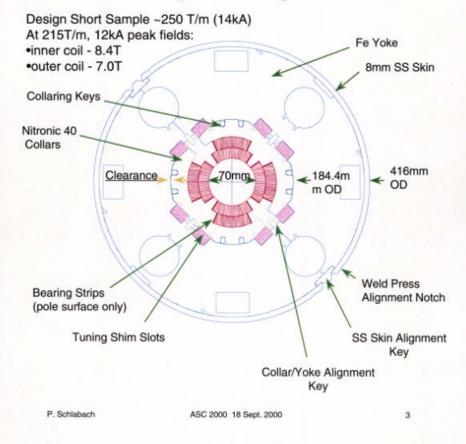
* "Some" include Directors of the world's HEP labs.



US LHC ACCELERATOR PROJECT

brookhaven - fermilab - berkeley

Baseline Design / Model Magnet Variants

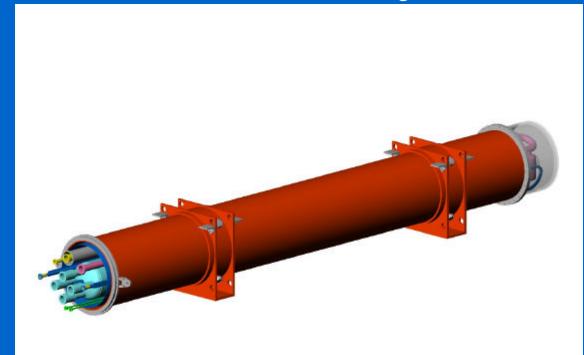


LHC IR Quadrupole Magnet (Cold Mass Only)

Courtesy Phil Schlabach

LHC IR Quadrupole Magnet

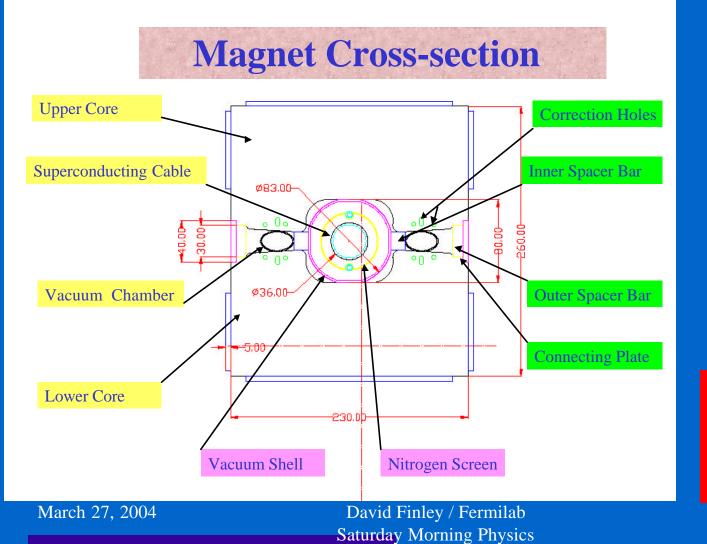
This quadrupole magnet is 36 inches in diameter and about 7 meters long



Fermilab is making several high gradient quadrupole magnets for the Interaction Regions at the LHC

VLHC - Low Field Option

(Very Large Hadron Collider)



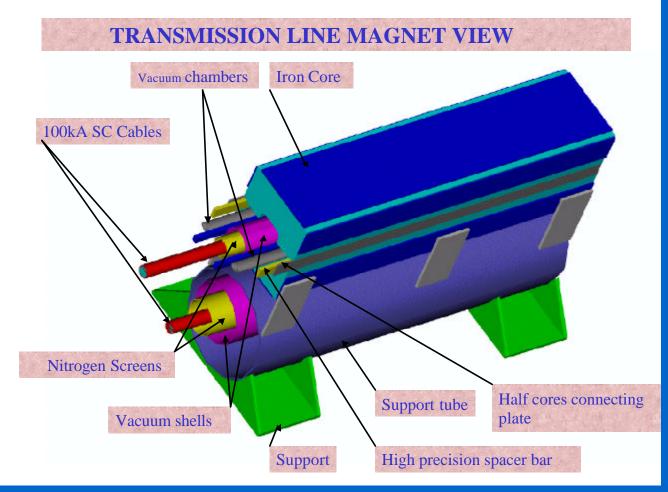
Courtesy:

G.W. Foster and

V. Kashikhin

May 2000

VLHC - Low Field Option



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David Finley / Fermilab Saturday Morning Physics Courtesy:

G.W. Foster and

V. Kashikhin

May 2000

VLHC - Low Field Option

Test Stand for the Field Measurement



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Courtesy:

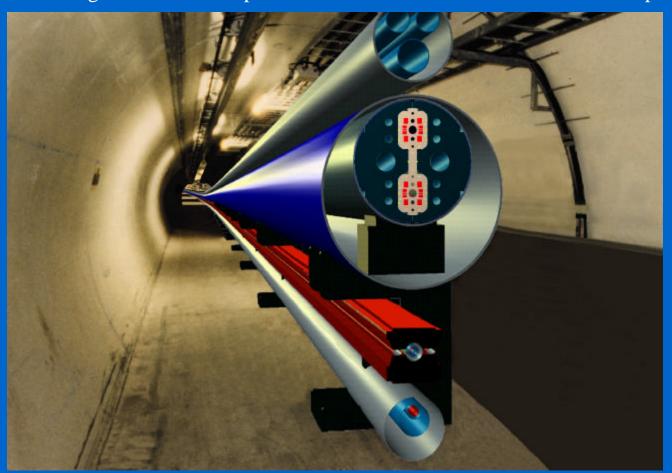
G.W. Foster and

V. Kashikhin

May 2000

A Tunnel Vision for the VLHC

Both high and low field options are shown in the LEP tunnel as an example.



The low field is on the bottom, the high field is on the top.

The tunnel is real and is about 12 feet in diameter.

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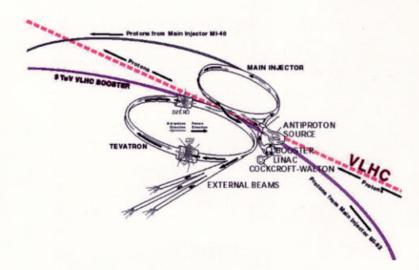
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Comments on a U.S. site at Fermilab:

Geology and Tunneling

The U.S. site of the vlhc is assumed to be Fermilab.

- · Existence of the injector chain
- Excellent Geology

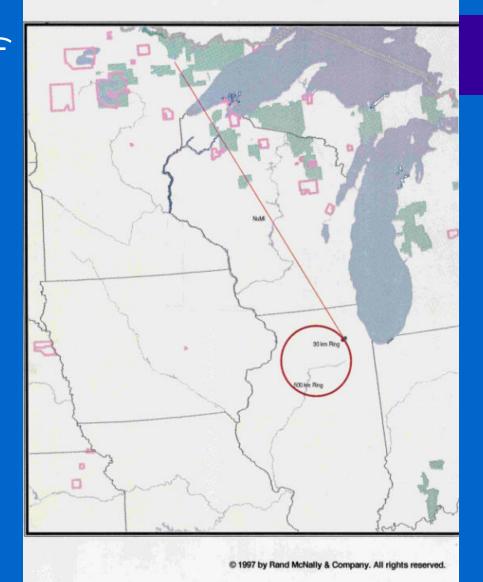


VLHC

Why put the VLHC at Fermilab?

Courtesy E. Malamud malamud@fnal.gov

500 km Pipetron Map Study



VLHC

Recall it is named "very large" for a good reason.

It would not really be "at Fermilab".

Rather it would be under "Northern Illinois"

But the NuMI neutrino beam will go from Fermilab to northern Minnesota starting next year.

(Yes, under Wisconsin!).

Muons on Muons ... Good News

- The good news is:
 - Just another simple lepton ... just like the electron
 - But heavier than the electron
 - They don't radiate photons like crazy
 - They interact better (40,000 times better) with Higgs
 - Q3: How do particles come by their mass?

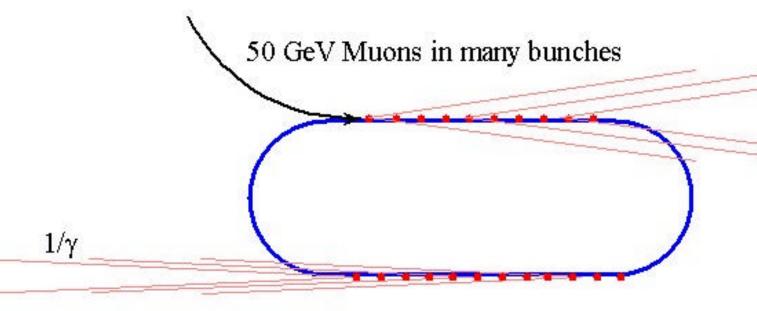
Muons on Muons ... Bad News

- The bad news is:
 - They only stay around for 0.000 002 seconds (or so)
 - They spit out electrons ... which then radiate like crazy
 - And they spit out neutrinos ... hmmm ...
 - Is this short lifetime so bad?
 - Can it be used to our advantage? >>> See next slides

Neutrino Factory

Concept (from Steve Geer / Fermilab)

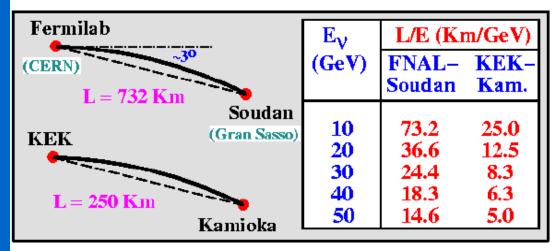
Muon Storage Ring as a Neutrino Source

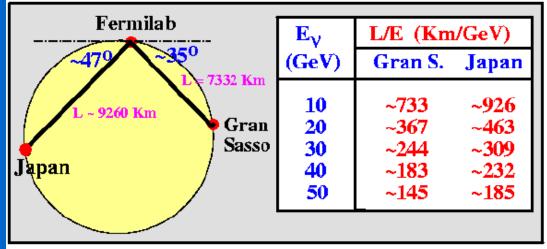


Medium baseline experiment eg Fermi -> SLAC/LBNL

2900 km

	L (km)	Dip (Deg.)	Heading (Deg.)
FNAL -> Soudan	732	3	336
FNAL -> Gran Sasso	7332	35	50
FNAL -> Kamioka	9263	47	325





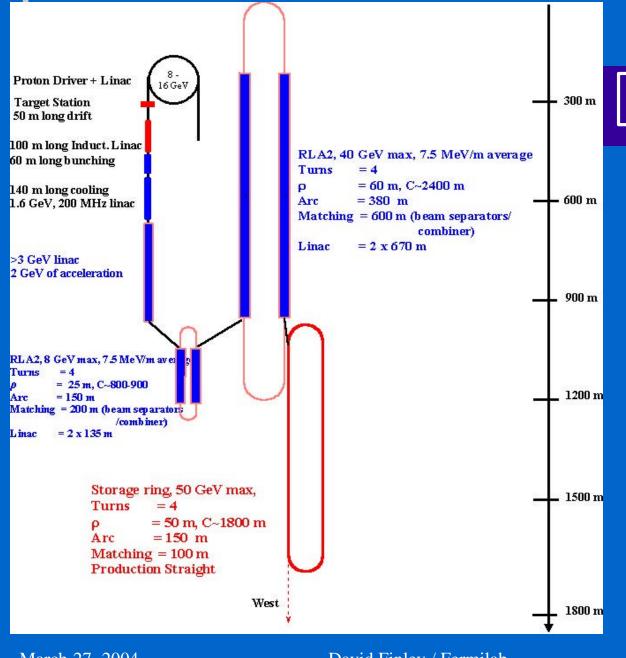
Neutrino Factory

Physics Guidance.

The Distance L
between the Neutrino
Source and Neutrino
Detector is important.

And so is the ratio of L to the Energy E of the neutrino beam.

Courtesy S. Geer



Neutrino Factory

Layout.

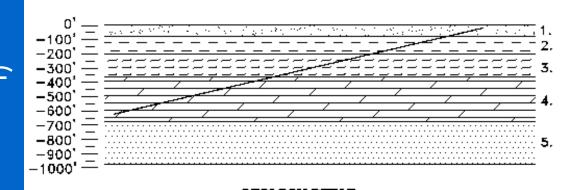
It takes a lot of things to feed it, but all together it is not so very large.

•

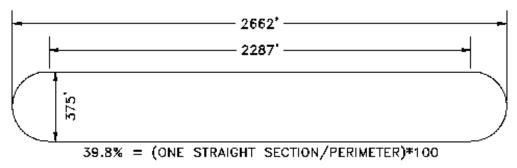
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- 1. The Aguifer
- 2. _____ SILURIAN GROUP AQUIFER (PRIMARILY DOLOMITE)
- 3. \[\] \[\] \[\] \[\] \[\] MAQUOKETA GROUP AQUIFER (PRIMARILY SHALE)
- 4. GALENA / PLATTEVILLE GROUP AQUATARD (PRIMARILY DOLOMITE)
- 5. ANCEL GROUP AQUIFER (PRIMARILY SANDSTONE)



CJ 2.0 LATTICE PLAN

Neutrino Factory

Design.

We need to aim DOWN ... so ...

What's under Fermilab?

A Neutrino Factory at Fermilab





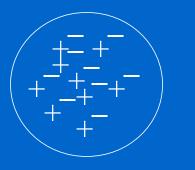
Neutrino Beam

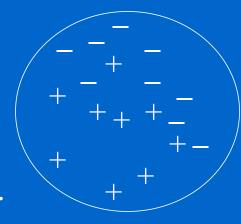
- The good news is:
 - All the muons decay to electrons and neutrinos
 - Never been done ... surprises probably in store
 - Q1, Q2, Q3, Q4, Q4++
- The bad news is:
 - Not discovery, not simple ... So, maybe not "interesting"?
- Aside: Really global-sized experiments

And Into the Beyond ...

- The good news AND the bad news is:
 - Hasn't been done before ...
 - For good reasons, usually ...
- One example is Plasma acceleration
 - 100 TeV center of mass ... and ...
 - All the equipment fits on the Fermilab site
 - But is costs too much to operate ...
 - At least ... using today's ideas and technology

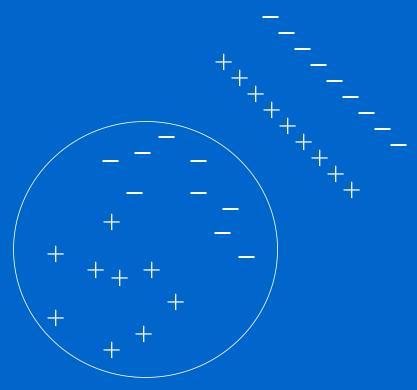
• How is it made?





Pull Them ...

Ideal (but highly unstable)



Pull Them Apart!

• How does it act?

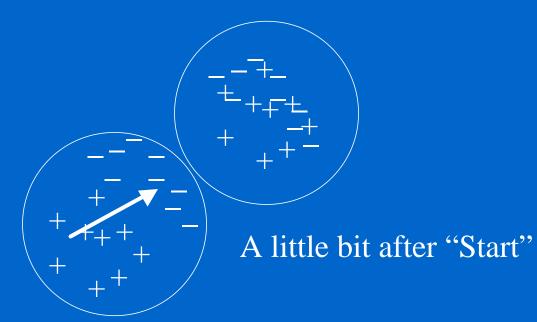




Start



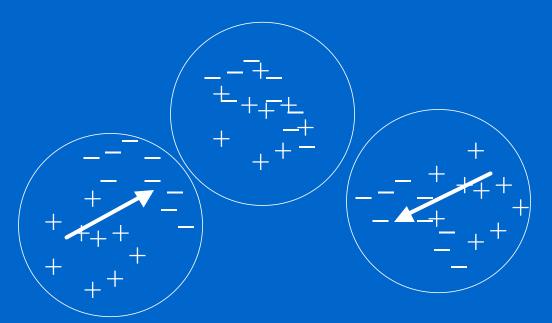




Time goes this way

• How does it act?





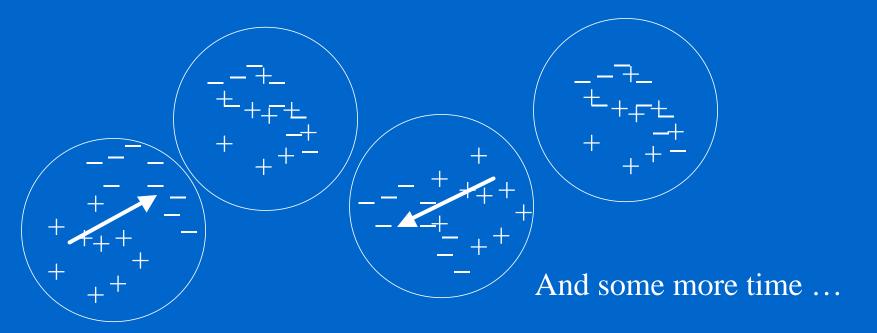
After some more time ...

Time goes this way



• How does it act?

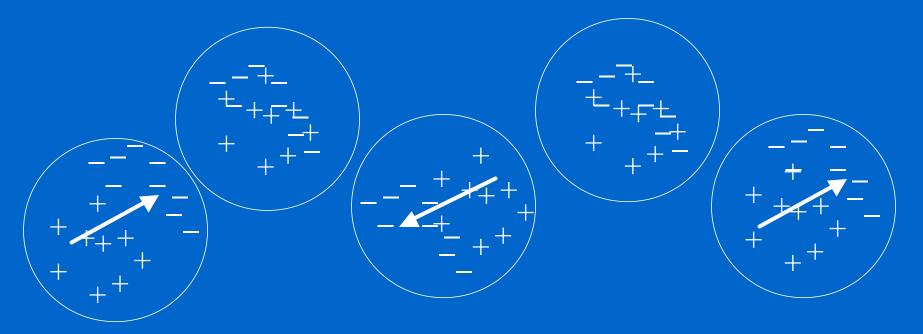
Electric Field



Time goes this way □

• How does it act?

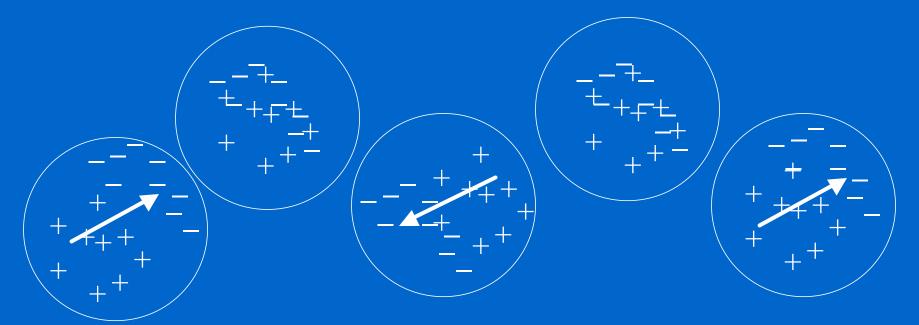
Electric Field



Time goes this way

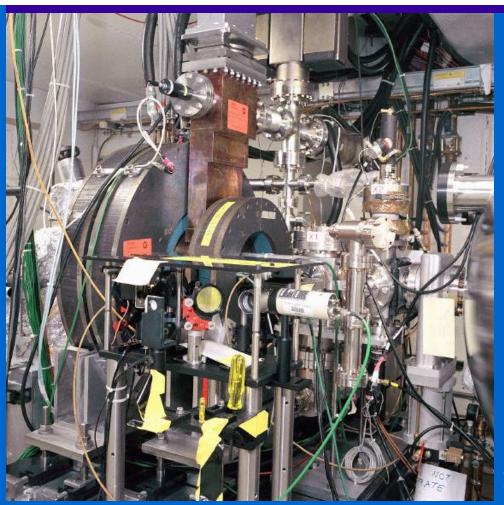


Electric Field



One "Plasma Period"

A0 Photoinjector at Fermilab



RF Gun and focussing solenoids

NIU (Northern Illinios University) is now heavily involved with this project.

http://www-ap.fnal.gov/A0PI/a0pics.html

A0 Photoinjector at Fermilab



Spectrometer magnets, plasma chamber, and beam dump

http://www-ap.fnal.gov/A0PI/a0pics.html

Summary

- This is still fun.
 - Q1: So what IS it all made of? and
 - Q2: How DOES it all behave? etc etc

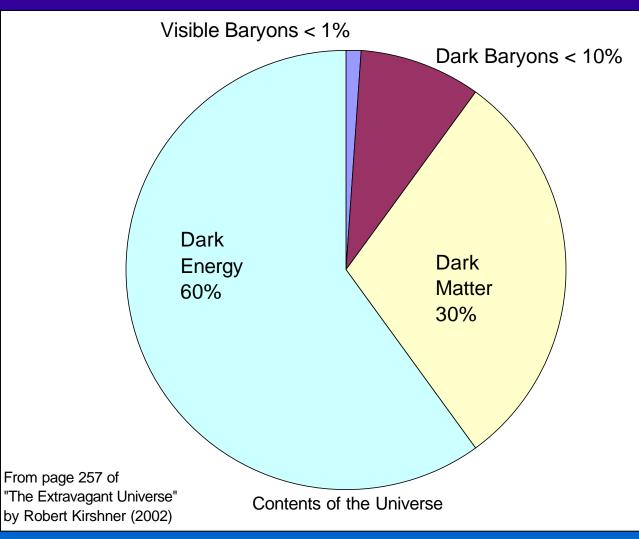
- There is still lots to do.
 - Decades (in performance and on calendars)
 - The best ideas are yet to come ...

Q1: What's it all made of?

Figure 11.4.

The Universal Pie. Although we can be proud that we have filled up this diagram, the biggest slice of energy-density in the universe is dark energy, which we don't understand, and the next biggest is dark matter, which we don't understand. There is plenty of work to be done.

Courtesy of Peter Garvavich, University of Notre Dame. March 27, 2004



That's It From Me ... And Now For Today's Tour

www.fnal.gov



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Your Host: David Finley finley@fnal.gov

